
Status of Coral Reef Ecosystem Mapping Activities

U.S. Coral Reef Task Force

Mapping and Information Synthesis Working Group

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NOAA/NASA Status Report

1) The first global map of tropical shallow water has been created through a joint effort of NASA and NOAA. Nearly 44,000 SeaWiFS (Sea-viewing Wide Field-of-View Sensor) scenes collected over five years were processed to 1 sq. km cells by NASA Space Flight Center using algorithms developed by NOAA for water shallower than 20-30 meters. NOAA is working with the United Nations Environment Programme World Conservation Monitoring Centre (WCMC) to use this data set to improve the database of coral reef locations used in ReefBase. The SeaWiFS map is being used as a reference for other imagery. The web address to display the map is <http://seawifs.gsfc.nasa.gov/reefs/>.

2) NASA's Oceanography Program is working with the Institute for Marine Remote Sensing (IMaRS) at the University of South Florida (USF) to provide an exhaustive worldwide inventory of coral reefs using high-resolution satellite imagery. By using a consistent dataset of high-resolution (30 meter) multispectral Landsat 7 images acquired between 1999 and 2002, USF intends to characterize, map and estimate the extent of shallow

coral reef ecosystems in the main coral reef provinces (Caribbean-Atlantic, Pacific, Indo-Pacific, Red Sea). For more information, please visit: <http://imars.usf.edu/corals/index.html>.

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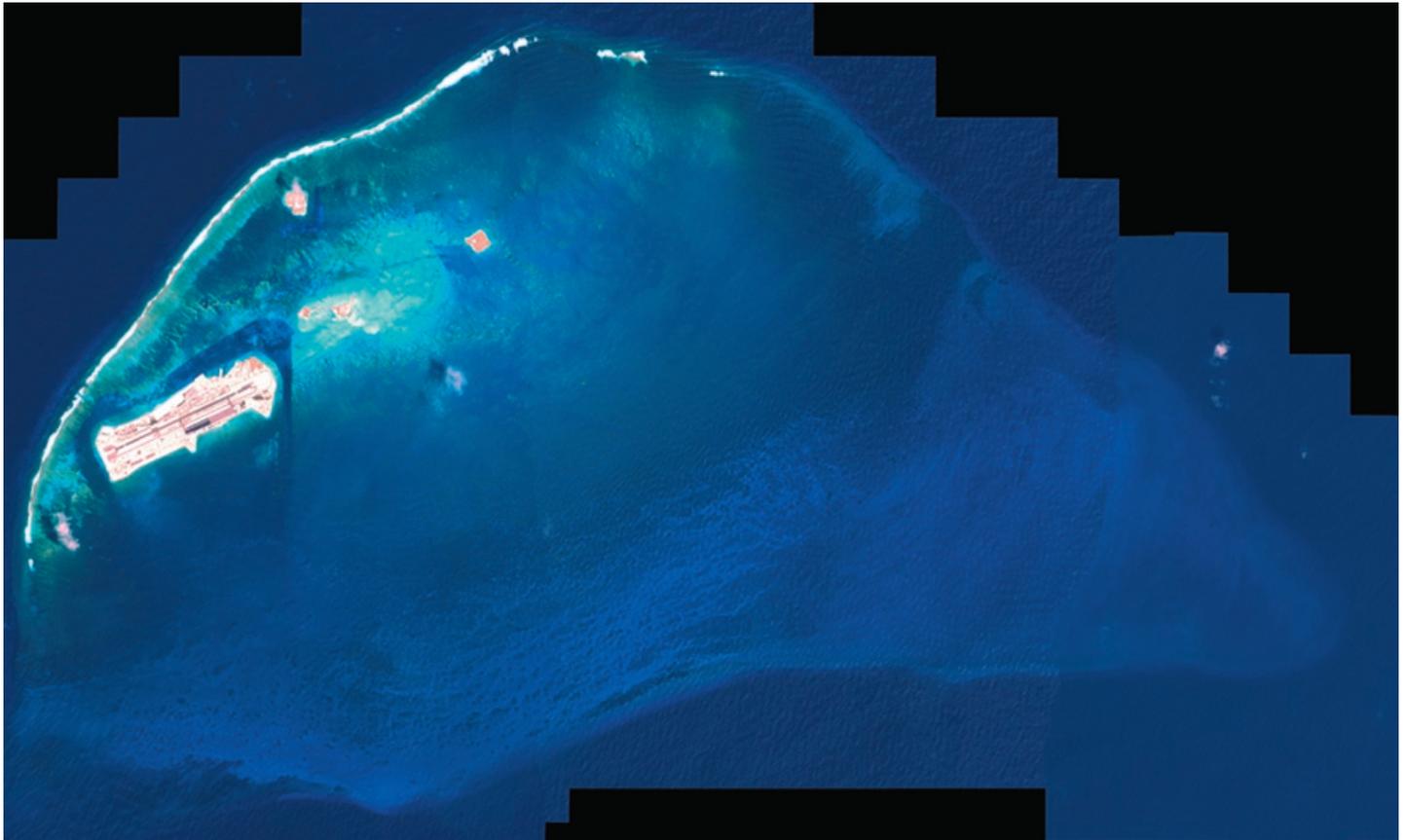
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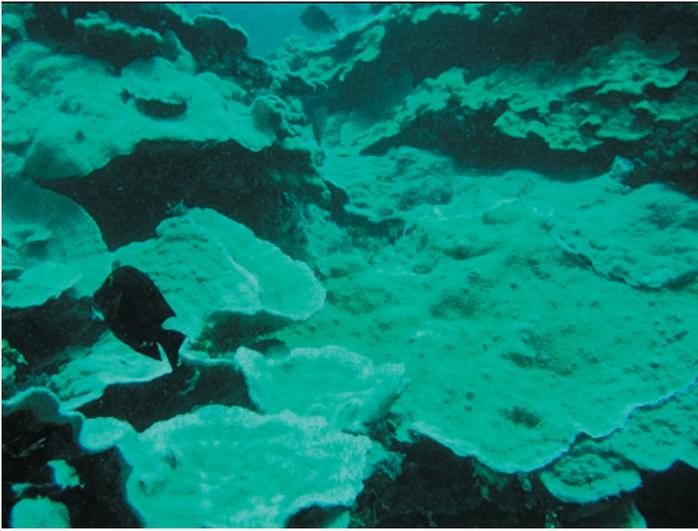
Many of the projects described in this section are funded, in part, through the NOAA Coral Reef Conservation Program.

1) In 2002, NOAA collaborated with a seven university, federal, state, and non-profit organizations to conduct over 1,800 SCUBA dives along the reef tract of the Florida Keys. Included in the effort was the collection of data to support coral reef habitat characterization.

2) NOAA partnered with the Hawaii Department of Land and Natural Resources, Bishop Museum, University of Hawaii, University of California-Santa Cruz, and the Waikiki Aquarium to conduct and extensive habitat

An IKONOS satellite image of Johnston Atoll, Pacific Ocean.





characterization and survey mission to the Northwestern Hawaiian Islands. Nearly 190 SCUBA surveys were completed.

3) In 2002, NOAA conducted the first survey in 17 years of the coral reef ecosystems of American Samoa. NOAA partnered with the Government of American Samoa, the University of Hawaii, Oregon State University, U.S. Fish and Wildlife Service, and the Bishop Museum to conduct over 100 towed diver surveys, collect nearly 1000 km of acoustic survey data, and 90 fish and benthic characterization assessments. During this mission, NOAA also visited many of the U.S. Line and Phoenix Islands.

4) In 2002, NOAA continued to develop techniques to support mapping efforts in the Pacific. A multibeam and backscatter instrument was purchased and is being installed on a shallow-water launch. A towed optical assessment device has been developed to provide digital still and video imagery of objects in water down to 100 m depths. Techniques to process acoustic data to produce maps also were developed.

5) In 2002, NOAA partnered with the University of Hawaii to conduct a 25-day multibeam and backscatter data gathering mission in the Northwestern Hawaiian Islands. The *Kilo Moana* collected data to locate the 25, 50, and 100 fathom isobaths for important island and bank areas. The data are being processed in partnership with the University of Hawaii.

6) Delivery of coral reef mapping products: Maps of the shallow-water coral reef ecosystems in the U.S. Caribbean were completed and published on both the web and as CD-ROM products in January 2002. Recent deliverables include:

- Maps of the shallow-water coral reef ecosystems of the Northwestern Hawaiian Islands (NWHI) have been completed. An 11" X 17" color Atlas, CD-ROM product, and web site are now available (<http://ccmaserver.nos.noaa.gov/rsd/products.html>).

- Maps of the shallow-water coral reef ecosystems for approximately 60 percent of the main Hawaiian Islands were made available in March 2003. These maps depict those portions of the shoreline where most coral reefs are present. A CD-ROM product and web site are now available and provide access to this information (http://biogeo.nos.noaa.gov/products/hawaii_cd).

- The Coral Reef Ecosystem Investigation recently compiled the [Bathymetric Atlas of the Northwestern Hawaiian Islands: A Planning Document for Benthic Habitat Mapping-Draft](#). This Atlas graphically summarizes the extent of multibeam and single-beam bathymetric data, LIDAR, and IKONOS-based estimated depth data for that area. Similar Atlases need to be developed for the main Hawaiian Islands, American Samoa, Guam, and the Northern Marianas.

- The Northwestern Hawaiian Islands-Spatial Bibliography (NWHI-SB) is a science planning tool with baseline information to help NOAA and partners to set priorities for future research and project investments in the Northwestern Hawaiian Islands. It's main purpose is to provide the user with reference or data information either by spatial area or by keyword searches. This system will allow scientists to reduce duplicative research, prioritize their efforts in the NWHI region, and identify obvious research partnerships. The NWHI-SB will include the following information:

- Suitable Basemap for NWHI;
- Spatial locations of key characterization information;
- Published studies;
- Collective team knowledge;
- Interviews with local partners (NOAA, USGS, USFWS, DLNR, NGO's, Universities, etc.);
- Bibliographical and metadata search of data (what, how, when, who, methods, etc.).

- In 2001, the NMFS mapped and characterized the Oculina Banks Habitat Area of Particular Concern in water down to 150 m using Clelia submersible equipped





An IKONOS satellite image of Palmyra Atoll, Pacific Ocean.

with video camera. The Oculina Banks Habitat Area of Particular Concern (OHAPC), home to the Ivory Tree Coral, *Oculina*, is characterized by a history of snapper and grouper overfishing and severe coral destruction. The OHAPC was established in 1984, closed to fishing in 1994 and expanded in 2000 to an area of 300 nm². Partners: NURP, NOS, USGS, HBOI, FSU, USF, NASA, and the Cambrian Foundation.

- In 2002, the NMFS conducted a multibeam echosounder survey that provided the first ever high-resolution (3 meter), three-dimensional bathymetric map of the coral habitat in the OHAPC (generally less than 100 m and 50% of the total OHAPC area). NASA's 170-foot ship, M/V Liberty Star, supported the survey. The survey covered about 65% of the coral habitat inside the reserve. The biological and habitat assessments, along with historical video and data from the area, and the multibeam map will be used to develop highly detailed GIS Maps of the Oculina Banks. These studies will be used to determine how effective the Oculina Reserve is for protecting and conserving reef fish populations and essential fish habitat.

7) Status of on-going mapping activities:

- A contract has been signed with Science and Technology International, Inc. (STI) of Hawaii to remap the main Hawaiian Islands using digital, aircraft-based hyperspectral imagery. Maps are to be completed within 24 months.
- Mapping activities in American Samoa began in June 2002. Draft maps of the islands derived from IKONOS satellite imagery have been completed as of August 2003. A draft classification scheme has been reviewed and accepted by the local Coral Reef Advisory Group. Final versions of the maps, developed by STI, are expected in 2004 <<http://biogeo.nos.noaa.gov/projects/mapping/pacific/territories/data>>.
- A mapping plan for Guam was developed in August 2002 and NOAA is currently obtaining IKONOS satellite imagery of the island. The imagery will be provided to STI for map development and map products are

expected in 2004. A draft habitat classification scheme has been reviewed and accepted by the local steering group to initiate map development.

- A mapping plan for the Commonwealth of the Northern Marianas was developed in August 2002 and NOAA is currently obtaining IKONOS satellite imagery of the 15 locations. The imagery will be provided to STI for map development and map products are expected in 2004. A draft habitat classification scheme has been reviewed and accepted by the local steering group to initiate map development.

- NOAA developed a plan to comprehensively map the shallow to moderate depth (20-200 fathoms) coral reef ecosystems in the NWHI and U.S.-affiliated Pacific Islands using ship-based or aircraft-based technologies. A Steering Committee meeting was held in Hawaii in December 2002 and NOAA developed a mapping requirements document with input from the Western Pacific Regional Fisheries Management Council, NOAA Fisheries, the NWHI Coral Reef Ecosystem Reserve, and the Office of the Coast Survey. Additional input will be needed from state and territory organizations as the Mapping Implementation Plan is finalized and priorities for mapping activities are established <<http://biogeo.nos.noaa.gov/projects/mapping/>>.

8) In 2001 and 2002, NOAA worked with the U.S. Geological Survey, the Minerals Management Service, the University of South Florida, the University of New Hampshire, and the National Undersea Research Center at the University of North Carolina Wilmington to conduct mapping activities over several areas in the Florida region. The Madison-Swanson and Steamboat Lumps Marine Protected Areas in the Gulf of Mexico and the Oculina Habitat Area of Particular Concern in the Atlantic Ocean were characterized using multibeam acoustic technologies. Submersibles, ROVs, and stationary digital video arrays were used in the Gulf MPAs and the Oculina HAPC to groundtruth acoustic data. These high resolution maps allowed the design of a statistically robust, stratified random sampling regime which correlated fishery and habitat associations in the Gulf MPAs. Other mapping activities were conducted in the western and eastern Gulf, the Florida Keys, and North Carolina. Recent accomplishments and discoveries include:



- Madison-Swanson contains non-hermatypic coral encrusting exposed paleo-reefs, and to a lesser extent, exposed paleo-shoreline structures. Steamboat Lumps contains a limited amount of exposed paleo-reef habitat, however a significant area contains base rock overlain with a thin veneer of sand. Reef fish, particularly red grouper, have excavated this sand veneer, exposing the underlying rock and creating microhabitats which foster hard and soft coral recruitment. Christopher Gledhill (NOAA Fisheries-Pascagoula) and Andrew David (NOAA Fisheries-Panama City) led this project.

- Open-file reports of the Gulf of Mexico MPAs multibeam maps are available on the USGS website and linked to from several NOAA Fisheries' websites.

- NOAA Fisheries' oral and written presentations to the Gulf of Mexico Fishery Management Council identified increases in abundance and distribution of reef fish within the Gulf MPAs, which lead, in part, to the Council's decision to extend the experimental closures for an additional six years (expiration June 16, 2010).

- A GIS was produced of the existing maps, fishery data, and coral restoration efforts within the Oculina HAPC. Several of the research cruises funded through the CRI incorporated live webcasts and featured extensive outreach and education components, including teacher- and student-at-sea activities. Stacey Harter and Andrew David (NOAA Fisheries-Panama City) led the NOAA participation in this project.

- Additional NOAA-funded mapping projects in the southeast included the Ten Fathom Ledge off North Carolina (Mike Burton - NOAA Fisheries-Beaufort), the Flower Gardens off Texas (Ron Hill - NOAA Fisheries-Galveston / Texas A&M), Pulley Ridge and the Florida Middle Grounds off the west coast of Florida (David Naar - USF / Felicia Coleman and Chris Koenig - FSU), and in the Florida Keys (Anne Marie Eklund - NOAA Fisheries-Miami).

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USGS Status Report

Pacific Region

USGS mapping activities in the Pacific Region focused on the Hawaiian Islands and have involved satellite, airborne, and boat-based sensors. Pacific Region mapping investigations resulted in the following accomplishments during the past year:

1) Application of Satellite Sensors:

- Two on-land runoff events that produced a large amount of suspended sediment onto the reef were captured using satellite images, as well as aerial imaging for the larger of the two runoff events. These data are being used to map and study the spatial distribution, transport patterns, and amount of sediment introduced onto the reef and its potential impact to the reef. To go along with these and other data sets an extensive set of digital photographs collected from three on-land automatic digital camera stations are being used to study both the resuspension of sediment by winds on the inner reef and the influx of new sediment due to on-land runoff caused by rain storms. Each of the digital camera stations has automatically been taking four photographs per day for 15 months for this component of the USGS coral reef project.

2) Application of Airborne Sensors:

- Generated detailed image maps by merging a





SHOALS shaded relief image and one-meter resolution aerial image mosaics of south and east Molokai, as well as south Oahu.

- Generated one-foot resolution image maps covering the coastal waters of south Molokai and south Oahu.
- Generated a Potential Coral Habitat Map (PCHM) of south and east Molokai using the SHOALS bathymetry data set.
- Used SHOALS data from south Molokai to analyze the origin and growth of spur-and-groove structures on coral reefs.
- A new airborne digital camera system was put together having spectral bands optimized for clear water penetration and suspended sediment detection and mapping. Besides having 10-bit radiometric/ brightness range for imaging the low radiance levels of coastal waters, it is quite portable and easy to transport making it ideal for capturing short lived events, such as on-land runoff events caused by rain storms.

3) Boat-Based Sensors:

- Researched the mapping of coral reef waters in depth from 20 to 120 feet using dual frequency acoustics. An image map showing 1st order benthic cover types along the south coast of Molokai was generated.
- Collected drop-down digital camera video at 540 points along the south and east coastal waters of Molokai ranging in water depth from 20 to 120 feet. These data were collected from a boat with good GPS location so that they can be used as ground truth and validation information for the various image maps being generated.
- Completed acoustic survey of the south Molokai reef to determine structure and history and results in publication process."

- An underwater imaging system was deployed off Molokai to obtain photographs of coral substrate at 6 hour intervals to evaluate sediment impact.

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Caribbean Region

1) In 2001 and 2002, NOAA worked with the U.S. Geological Survey, the Mineral Management Service, and the University of New Hampshire to conduct mapping activities over several areas in the Florida area. The Madison-Swanson and Steamboat Lump area in the Gulf of Mexico and the Oculina reef areas in the Atlantic Ocean were characterized using multibeam acoustic technologies. Submersibles also were used over the Oculina reefs.

2) Northern Florida Keys: Coral reef ecosystem mapping undertaken by the USGS in the northern portion of the Florida Keys reef tract centered on the development and application of a new submarine topographic lidar in close collaboration with NASA, the Experimental Advanced Airborne Research Lidar (EAARL). The NASA EAARL is a temporal waveform-resolving, airborne green wavelength lidar that is designed to measure the topographic complexity of shallow reef substrates. Recent accomplishments include:

- Creation of the Airborne Lidar Processing System (ALPS) for both the interactive and batch processing of EAARL data sets. ALPS supports the exploration and processing of lidar data sets collected by EAARL overflights. Modules for flightline and derived-variable map creation, lidar raster and waveform investigation, and digital camera image playback are now functional.
- Construction and testing of algorithms for the retrieval of submarine topography, and vegetation (i.e., mangrove) height and density. Procedures for the analysis of lidar temporal waveforms to extract submarine / subaerial topography, and vegetation canopy variables, have been developed and embedded within ALPS.
- Development of quality control methods for NASA EAARL submarine topographic data sets. Methods for the removal of spurious elevation estimates within processed EAARL data sets have been created based on random consensus filtering techniques and comparison to ancillary data.
- Lidar swath-mapping of the northern Florida Keys reef tract. In August 2002, the EAARL was used to swath-map a portion of the Florida Keys reef tract that extends from the northern tip of Elliot Key to south of Carysfort Reef.
- Development and testing of optical rugosity analysis

on northern Florida Keys reefs. Habitat topographic complexity, or rugosity, both expresses and controls the abundance and distribution of many reef organisms. An optical rugosity analysis based on August 2002 EAARL surveys of the northern Florida reef tract revealed that the higher habitat complexity of inshore patch reefs versus outer bank reefs results in relative differences in topographic complexity that can be sensed by the EAARL.

3) Southern Florida Keys: Pulley Ridge, a 100+ km-long series of N-S trending, drowned, barrier islands on the southwest Florida Shelf approximately 250 km west of Cape Sable, Florida, was mapped using multibeam bathymetry, submarines and remotely operated vehicles, and a variety of geophysical tools. The ridge is a subtle feature about 5 km across with less than 10 m of relief. The shallowest parts of the ridge are about 60 m deep. These mapping activities have recently resulted in the following discoveries concerning the deep water coral reef ecosystem at Pulley Ridge:

- Surprisingly at this depth, the southern portion of the ridge hosts an unusual variety of zooxanthellate scleractinian corals, green, red and brown macro algae, and typically shallow-water tropical fishes.
- The corals *Agaricia* sp. and *Leptoceris cucullata* are most abundant, and are deeply pigmented in shades of tan-brown and blue-purple, respectively. Less common species include *Montastrea cavernosa*, *Madracis formosa*, *M. decactis*, *Porities divaricata*, and *Oculina tellena*. Sponges, calcareous and fleshy algae, octocorals, and sediment occupy surfaces between the corals. Coralline algal nodule and cobble zones surround much of the ridge in deeper water (greater than 80 m).
- In addition to coralline algae other abundant macro algae include *Halimeda tuna*, *Lobophora variegata*, *Ventricaria ventricosa*, *Verdigelas peltata*, *Dictyota* sp., *Kallymenia* sp., and particularly striking fields of *Andaymonene menzeii*. The latter algae covers many hectares at densities of tens of individuals per square meter, constructing regions that appear like lettuce fields growing in the dusk at this depth on the sea floor.
- Mounds and pits larger than 1m² are apparent on side-scan sonar images and have been counted in excess of 200/km² for parts of the ridge.
- The extent of algal cover and abundance of herbivores suggest benthic productivity is moderate to high on parts of the ridge. Such productivity is unusual, if not unique at this depth in the Gulf of Mexico and Caribbean.
- Notwithstanding the positive factors for reef growth listed above, this largely photosynthetic community appears to be thriving on 1-2% (5-30 microEinsteins/

m²/sec) of the available surface light (PAR) and about 5% of the light typically available to shallow-water reefs (500 – 1000 microEinsteins/m²/sec). The corals generally appear to be healthy, with no obvious evidence of coral bleaching or disease.

- Southern Pulley Ridge may well be the deepest coral reef in the United States, however, this is a definitional issue. From a geologist's point of view, Pulley Ridge corals appear to have built a biostrome, an accumulation at least a few meters thick, although corals may not account for the bulk of the topography. From that of a biologist, the most abundant corals in the ridge are hermatypic corals but they are lying, mostly unattached, on the surface.

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